Ecology

Project title: The Ecological Relationship Between a Rocky Mountain Threatened Species and a Great Plains Agricultural Pest

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Objectives: 1) To determine where army cutworm moths (*Euxoa auxiliaris*) (ACMs) originate. Pressures on ACM subpopulations, either natural (e.g., weather patterns) or human-caused (e.g., pesticides, habitat conversion), may affect moth recruitment and the numbers of adults reaching high elevation sites, where they are a critical food source for the threatened Greater Yellowstone Ecosystem grizzly bear (*Ursus arctos horribilis*). 2) To determine if ACMs harbor agricultural pesticide residues in their tissues. Resulting pesticide magnification in grizzly bears that forage heavily on moths may have detrimental physiological or developmental side effects. 3) To elucidate the effects of weather on ACM migration from Great Plains agricultural areas to ACM aggregation sites in the Rocky Mountains. 4) To determine whether ACMs from different Great Plains origins are interbreeding in high elevation sites prior to their return to agricultural areas. If ACM subpopulations do not interbreed, unfavorable conditions in specific Great Plains areas may impact moth numbers in high elevation.

Findings: To date, army cutworm moths (*Euxoa auxiliaris*) (ACMs) have been collected for genetic and reproductive analyses from a total of 11 high elevation sites, including nine sites in Wyoming, one site in Washington, and one site in New Mexico. ACMs have been collected from 39 low elevation sites in Montana, Wyoming, Nebraska, and South Dakota. The sampling effort comprises a 360-degree radius around the high elevation study areas.

ACMs were collected for pesticide residue analysis during the 1999 and 2001 field seasons. Analyses of these ACMs showed no biologically significant traces of pesticides in the ACMs. Genetic analyses on the ACMs are performed in the Laboratory for Ecological and Evolutionary Genetics at the University of Nevada, Reno. Each of these several thousand ACMs must be individually keyed out to species and then their DNA may be extracted. A genomic DNA library was developed for the ACM. This library was screened for microsatellite loci and primers were developed to amplify these loci in polymerase chain reactions (PCRs). PCRs are being optimized for these loci, and analysis of the variability at these loci is beginning. Analysis of the variability at these loci will aid in determining whether ACMs interbreed in high elevations and in determining their Great Plains origins.

Project title: Collection and Use of Plaster Castings of Animal Tracks to Teach Wildlife Ecology to College and K-12 Students

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Objective: We propose to collect plaster casts of animal tracks that we find along the Lamar River and Soda Butte Creek. This exercise will be conducted during a three credit field course offered through the University of Wisconsin–Whitewater for college students and K–12 educators. We wish to introduce wildlife management techniques such as track interpretation. Participants will be asked to identify tracks (to genus and species if possible), interpret any behavior suggested by the tracks and prepare plaster castings. Many of the participants are, or plan to become K–12 teachers, and these techniques will be useful in outdoor education. Selected castings will be used for later testing of the participants during course exams. Selected castings will also be displayed in a comparative and interpretive collection at the University of Wisconsin–Whitewater, Biology Museum. The castings will also be used in the University of Wisconsin–Whitewater Outreach Program for K–12 schools and local Scout troops. The castings are used to make latex negatives for duplication of the original. These duplicates are then used in lectures about wildlife ecology and Yellowstone National Park given by Dr. Clokey. Each year, 10–20 duplicate castings are made and distributed to a K–12 class during the lecture. All castings are for educational purposes only and are not for sale (they are marked with the collection location, animal and a statement saying not for sale). Participants in the course are allowed to keep duplicates of castings and are told that they are to be used for educational purposes only. We collect within 200 yards of established trails. We are discreet and clean up all plaster and material. We are aware of and respect the rights and interest of other users.

Findings: Tracks of coyote, wolf, grizzly bear, bison, pronghorn and raven were studied along the Lamar River and Soda Butte Creek. About 7–10 plaster casts were made for the bear and wolf tracks each and two casts were made for each of the other species. Selected castings were used for educational purposes at the University of Wisconsin–Whitewater Museum (we kept several good wolf tracks and one good bear track for the University display). Students in the course were allowed to keep duplicates of the bear and wolf tracks. We plan to continue teaching the course until 2005 and will seek permission to collect similar tracks at the same locations each year.

Project title: The Sustainability of Grazing Ecosystems

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Objective: Examine the effects of grazing mammals on grassland primary production and nutrient cycling.

Findings: In 1998, we established 10 grassland sites in the park ranging widely in elevation, seasonal use by ungulates, plant production, and soil conditions. At each site, we established permanent exclosures to create an ungrazed treatment. Since 1999, we have measured aboveground and belowground production inside and outside the exclosures at each of the sites to determine the effect of grazing on grassland production. In addition, in 2001, we measured in situ net N mineralization inside and outside exclosures at six of the sites.

Plant production data from 1999 indicate that ungulates increased both aboveground and belowground production. Belowground production was stimulated seven times more than aboveground production. Data from 2000 and 2001 are currently being analyzed. In addition, soil extractions from 2001 to examine the effects of grazers on N mineralization have not been analyzed.

Project title: The Impact of Climate Change on Alpine Plant and Insect Diversity in the Rocky Mountains

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Objectives: The goals of this study are to determine the impact of climate change on the biological diversity of alpine plants and insects in the Rocky Mountains and the degree to which national parks may conserve this diversity. These objectives will be accomplished by inferring the shared phylogeographic history of alpine plants and insects through genetic analysis of the geographic structure and history of populations of plant-insect associations throughout the Rockies. This analysis will not only reveal how historic climate change affected population structure, but also permits the identification of national parks that harbor relatively high levels of diversity.

First, it must be determined whether independent taxa share a common history. The null hypothesis is that the phylogeographic history of each species is unique. The null predicts no concordance in the timing of diversification events or topography among area cladograms for the different taxa. The alternative hypothesis is that independent taxa share a common history and predicts that co-distributed species will have similar area cladograms.

The shared history of taxa will be used to estimate how extrinsic factors contributed to the distribution and diversity of these co-distributed organisms. The null hypothesis is that there is no geographic structure to the distribution of diversity. This hypothesis predicts that geographic lineages are distributed randomly on a phylogenetic tree. Analysis of the historic shifts in the distributions of alpine habitats suggests an alternative hypothesis that the southern Rockies served as a refuge and harbored species for longer periods of time than northern portions of the modern range. This hypothesis predicts that lineages in northern populations will be more recently derived than southern populations and only a fraction of the diversity present in the south will be represented in the north.

The study taxa: In order to acquire a representative sample of the alpine community and incorporate interspecific interactions into the examination of how climate change affected biological diversity, this study will analyze the phylogenetic histories of three specialized plant-insect interactions. These associations 1) range from the southern Rockies where the effects of habitat fragmentation due to climate change are most severe to northern areas that were completely covered by Pleistocene ice sheets, 2) are predominantly influenced by climate, 3) are abundant and play integral roles in the alpine community, 4) are relatively easy to find and collect, and 5) include taxa for which molecular techniques are well developed. Herbaceous plants and insects have been shown to be excellent bio-indicators of climate and environmental change.

Two pairs of alpine plant–butterfly associations will be used to estimate the geographic distribution of biological diversity. The study organisms are 1) the yellow stonecrop *Sedum lanceolatum (Crassulaceae)* and the Rocky Mountain Apollo *Parnassius phoebus* (*Papilionidae*) and 2) the alpine clover *Trifolium dasyphyllum (Fabaceae)* and Mead's sulfur *Colias meadii (Pieridae)*. Though the associations are relatively specific, variation in host use occurs throughout each species' range.

Findings: Specimens of *Sedum lanceolatum*, *Parnassius phoebus*, *Trifolium dasyphyllum*, and *Colias meadii* were collected from 22 alpine sites throughout the Rocky Mountains, including Glacier National Park, the Greater Yellowstone Ecosystem, Rocky Mountain National Park, and the southern Rockies of Colorado. In Glacier National Park specimens were collected at 1) Numa Peak, 2) Gunsight Mountain, 3) Triple Divide Peak, and 4) Dawson Pass. In the Greater Yellowstone Ecosystem, the alpine sites in Yellowstone National Park were on 5) Amethyst Peak and 6) Mt. Washburn, while in Grand Teton National Park, specimens were collected from 7) Moose Mountain and 8) Static Peak. Organisms were collected from alpine tundra in Rocky Mountain National Park on 9) Sundance Mountain and 10) Long's Peak. Specimens were also collected from eastern slope sites in Idaho, including 11) Hyndman Peak and 12) Borah Peak, and from potential southern refugia sites in Colorado including: 13) the American Basin, 14) San Luis Peak, 15) Humboldt Peak, 16) Iron Nipple, 17) Mt. Democrat, 18) Mt. Elbert, 19) Mt. Shavano, 20) Quandary Peak, 21) Maroon Pass, and 22) Pike's Peak.

In order to obtain an accurate estimate of genetic variation and thus population history, it is necessary to sample DNA from many individuals of each population. Twenty to thirty specimens of each species were collected at each site. Sites were accessed on foot. Butterflies were collected with a net and stored in glassine envelopes. To preserve the organisms and their natural environment, only parts of plants were collected. Leaves were sampled by hand from approximately thirty individuals of each species and stored in plastic bags. Specimens were carried out of the field, transported on ice, and stored at 80°C at the University of Colorado, Boulder.

Methods for assessing evolutionary histories and diversity: Nuclear as well as mitochondrial (mtDNA, insect) or chloroplast (cpDNA, plant) DNA was sequenced, in order to develop phylogenetic trees. DNA was extracted from the insects and amplified with specific primers for the mitochondrial Cytochrome Oxidase I. DNA was extracted from the plants and amplified with specific primers for the chloroplast intergenic spacers between trnL and trnF and between trnL and trnT.

Phylogenetic trees and nested clades were generated from DNA sequence polymorphisms to infer hypothetical evolutionary relationships among haplotypes (unique genetic sequences) within each species.

Results to date: The strength of the historic signal between the herbivorous insect and its host-plant suggest that biotic factors may be responsible for evolution in these organisms, and that there is a strong potential for co-evolution. Importantly, these findings point to ecological and evolutionary stability of the alpine community. Preliminary analysis revealed significant co-divergence of the host plant *(Sedum)* and the herbivore *(Parnassius)* based on topology-based tests (using TreeMap).

A preliminary nested clade analysis reveals a geographic distinction between southern Colorado and northern haplotypes; however, too few individuals from each population have been sequenced at this juncture for a rigorous geographic analysis of the clades. This pattern is also evident from the plot of genetic variation with latitude. Though only a few individuals from each population have been analyzed, these data agree with the general trend of rapid northward expansion following deglaciation and contrast the findings of other alpine studies.

Together, these preliminary findings support the hypothesis that alpine communities persist in southern refugia and northern were re-colonized following glacial retreat.

Project title: Northern Range Small Mammal Study: Populations Responding to Vegetation Change

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Objective: 1) Provide a continued, long term monitoring effort on the small mammals of Yellowstone's northern range to determine how populations respond to habitat changing events such as fire. 2) Evaluate the spatial and temporal distribution of small mammal species by developing improved and refined landscape (habitat) models that predict their distribution and abundance. 3) Re-assess the small mammal prey base in relation to the predators present in the northern range. 4) Monitor recolonization of small mammals and vegetation in habitats affected by the fires of 1988 (13 and 14 years later).

Findings: The data collected from last summer's field work has not been analyzed yet. We will complete analysis of the trapping data upon completion of the project after the summer of 2002. General trends that we observed over the course of the field work last summer were a reduction in vole population numbers, possibly as a result of drier conditions. We will examine these types of demographic relationships once we have the full data set collected.

Project title: Effects of Winter Range on a Pronghorn Population in Yellowstone National Park

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Objective: Describe seasonal movement patterns and distributional shifts in the pronghorn population. Model current patterns of landscape use on the pronghorn winter range. Relate patterns of seasonal landscape use with assessments of adult female pronghorn survival and recruitment.

Findings: The population contains two subgroups, based on migratory strategy with respect to the winter range. A non-migratory segment remains on the winter range year-round, a migratory segment summers from Blacktail Plateau to Lamar Valley, then returns to the winter range in the fall. There also has been movement out of the park to Carbella, where a herd has remained for the past 22 months. Selection among cover types on the winter range is occurring. Winter diet is comprised mostly of browse, with rabbitbrush being the most abundant plant type. Fawn doe ratios during the summer months are consistently lower for the non-migratory herd than for the migratory herd. There is a precipitous decline in fawn doe ratios from August to November. The herd on private land at Carbella has a fawn doe ratio of 1:1. The project is near completion. A final report to the park is expected in May 2002.

Project title: Causes for Habitat Selection of Uinta Ground Squirrel

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Objective: The Uinta Ground Squirrel is commonly found in both grassland and sagebrush habitats. The objective of this study is to determine what effects this change in vegetative structure has on individuals living within these habitats. The Uinta ground squirrel defends itself against predators by visually scanning its surroundings and assessing the danger while it forages above ground. Individuals within grasslands have a clear line of sight while scanning, typically allowing them ample time to spot an oncoming predator and retreat below ground. In the taller sagebrush, however, the individual's view is obscured, reducing predator detection ability. We seek to determine what effect this change in vegetative structure has on the individual's behavior, survival probability and baseline stress level. We will determine how the individual's behavior has changed in response to the taller vegetation by trapping individuals in Sherman live traps and placing a unique design on their back using commercial hair dye. This will allow us to observe known individuals and compile time budgets for each individual for comparison between populations in the two habitats. Through repeated trapping over the course of the summer long field season we will be able to determine survival of individuals and also determine the general health of individuals by documenting their weight gain over the course of the field season. Finally, we will retrieve fecal samples from the traps to determine the level of the stress hormone corticosterone that is found in the animal. This will allow us to determine if the reduced scanning ability has a negative physiological effect, which may effect survival probability. We anticipate finding an increase in vigilance behavior and stress hormone level as a result of the obscured surroundings within the sagebrush habitat and a possible reduction in survival probability due to the negative effects of stress and reduced predator scanning and avoidance ability.

Findings: At this time, we have not completed any statistical analysis of the data collected over the summer of 2001. We did collect a great deal of behavioral data as well as fecal samples for the stress hormone tests from individuals across age and sex classifications. We caught a total of 294 animals between the five field sites in the northern range. The general impression we have after this initial field season is that the individuals living within the sagebrush habitat are more wary of intruders than the relatively less wary individuals in the grassland. They demonstrated uneasiness with every sound and movement, while individuals in the grassland were seemingly relaxed unless directly rushed at by predators. Ultimately, they seemed far more secure and relaxed than their sagebrush conspecifics. We have not completed any stress tests, but our samples are being preserved in deep freeze until we can complete the tests in fall 2002. We anxiously await the results of our statistical analysis, which we will complete following our second and final field season in summer 2002.

Project title: Effects of 1998 Fires on Ecology of Coyotes in Yellowstone National Park: Baseline Succeeding Wolf Recovery

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Objective: Document long-term effects of the 1988 fires on the population dynamics and behavioral ecology of coyotes. Document the long-term impacts of wolf restoration on coyote populations and coyote behavioral ecology, including effects on coyote prey abundance, and competitor species. Continue long-term monitoring of coyote populations by adherence to those objectives listed in previous reports and peer-reviewed publications, including: pack size, individual identification, social class, pack location, mortality, loss rate, litter size, vocalizations, scent-marking, predation on small mammals and ungulates (and neonates), interactions with other species including ungulates, interactions with scavengers at carcasses, and radio-tracking.

Findings: This long-term project began phase III in 2001 (Phase I: pre-wolf, Phase II: wolf colonization, Phase III: wolf establishment). Each six-year phase provides a new segment of a rare long-term ecological study. The long-term impact of fires (during Phase I) was an indirect effect via the small mammal prey base but now these effects are diminishing. A variety of significant demographic and behavioral effects of wolves on coyotes continue to occur. Currently, 33 resident adult coyotes occupy the Lamar Valley and Little America study areas, with a much reduced population present on the Blacktail Plateau study area. The demographic and social disruption of resident coyotes in the central Lamar Valley that occurred during the initial wolf colonization period from 1995 to 1999 (and 1997 to present in Blacktail) was to a great extent replicated in the Little America area in the year 2000 and 2001, as the Druid wolf pack extended its use area to cover this portion of the coyote study area. Effects on coyotes included increased mortality and disappearance rates, high turnover of alpha pairs, extreme fluidity in home range boundaries and social composition, and a variety of other behavioral responses. Three manuscripts are currently in preparation this year, which delineate specifics of demographic, spatial, and mortality-related aspects of the study.

Project title: Sagebrush Ecology and Ungulate Relationships

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Objective: To 1) determine the current status of the sagebrush-shrub community on the northern Yellowstone mule deer winter range, 2) determine the importance of the sagebrush-shrub community to wintering mule deer and elk, 3) describe the effect of human-caused and natural fire, including interactions with browsing, on sagebrush ecology on the northern Yellowstone winter range, and 4) determine what management techniques can be implemented to preserve or enhance mule deer and elk habitats associated with sagebrush–shrub communities.

Findings: Mule deer utilize the several sagebrush habitat types in the boundary line area as key wintering types. They use the four woody sagebrush and three rabbitbrush heavily as browse, although they display a decided preference among taxa on winter range. None of the sagebrush have reestablished.

Project title: Ecology and Distribution of Red Fox (*Vulpes vulpes*) in Northern Yellowstone

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Objective: 1) Determine long-term trends in habitat use of northern Yellowstone's red fox and the potential influence of changing prey abundance, climate, and distributional shifts by coyotes, and 2) examine the genetic variability of red fox subpopulations according to three elevational zones.

Findings: The distribution, morphology, and habitat use of red fox was examined in the northern Yellowstone ecosystem. Morphological and genetic samples were collected on live-captured and dead foxes to identify the presence and distribution of potential red fox subspecies across an elevational gradient. Examination of 22 red foxes indicated shorter tail length above 7,200 feet. Other parameters indicated trends of beneficial adaptations to climatically harsh environments at high elevations. At elevations above 7,200 feet, there was significantly higher frequency of a light gray coat color morph. Genetic analysis indicated that foxes above 7,200 feet were genetical isolated from lower elevations yet no geographic barrier exists. Habitat use was evaluated by snow-tracking fox using GPS and GIS technologies. Foxes were distributed across the study area in a wide range of forest cover types. Results show that red fox prefer forested and forest-edge habitats. Foxes significantly selected habitats that were less than 25 meters from an ecotone (structural edge). They preferred mesic sedge meadows and spruce-fir habitats at low angle slopes with a wide range in aspect. Lower elevational populations on the northern range were less specific in their selection of habitats and foraged mostly in mesic meadows and sagebrush. Above 7,200 feet, foxes preferred spruce-fir forests and foraged in mesic meadows and in spruce-fir and old-aged lodgepole forests. The mountain red fox that inhabits northern Yellowstone should be classified as a forest carnivore and is quite possibly a new subspecies of mountain fox, indigenous to North America. Field work continued in winter 2001/2002 to re-survey transects covered in 1994 and 1995. One manuscript was submitted in 2001 and another is planned for 2002.

Project title: Above– and Below–ground Carbon Allocation in Developing and Mature Lodgepole Pine Forests in Yellowstone National Park

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Objective: Fire and landscape variables interact to produce a mosaic of different vegetation types. The resulting spatial heterogeneity in tree density, herbaceous cover, and species composition that has been observed in Yellowstone National Park will influence primary production and carbon storage for many years. Therefore to determine the long-term effects of fire on carbon release and storage during succession, we must understand how processes differ among sites as a function of community structure. The research we are conducting focuses on the effects of differences in growth-form composition (i.e., relative abundance of trees and herbaceous plants) on above- and belowground carbon dynamics following the 1988 fires in Yellowstone National Park.

The overreaching objectives are to answer two questions: 1) How do above- and belowground carbon storage and flux values differ in 12-yr-old post-fire stands with different proportions of trees and herbaceous plants? 2) How do above- and belowground carbon storage and flux values in stands burned 12 years ago differ from comparable values in nearby mature forests with similar soils?

Answering these questions will enable us to look more holistically at the effects of differences in growth-form composition carbon allocation across the Yellowstone landscape where lodgepole pine *(Pinus contorta* var. *latifolia)* is the dominant species.

Findings: A 3 1/2-month field season during the summer of 2001 allowed us to complete the field phase of our research, which encompassed 11 months of field work in Yellowstone NP over the last 3 years. Specific field accomplishments included: 1) sampled soil CO2 efflux rates early in the summer when soils were saturated from melting snowpack and soil temperatures were still relatively low; 2) conducted a comparison of our IRGA (EGM-2, PP-systems) with the recognized standard (LICOR-6400) for sampling soil CO2 efflux; 3) harvested the belowground portions of 45 trees to be used in the creation of allometric equations for estimating coarse root biomass in developing lodgepole pine trees; 4) completed data collection for above–ground net primary productivity estimation; 5) collected litter trap samples for estimating winter litterfall rates; 6) collected ion-exchange resin bags that were placed in the field during September of 2000; 7) harvested the above–ground portion of 5 mature lodgepole pine trees for validation of existing allometrics; 8) resampled soil, litter and root carbon pools to provide estimates of changes in these compartments.

All lab work has now been completed and we are currently analyzing our data and preparing manuscripts. We expect that three manuscripts will be submitted to peer reviewed journals within the next 6 months and that one dissertation will be completed as well. Copies of all documents will be sent to Yellowstone NP Research Office.

Project title: Graduate Program in Science Education, Classes in Geology and Ecology

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Objective: Educate graduate-level students in teaching and ecology coursework.

Findings: No research was conducted. All projects were of an educational nature.

Project title: Validation of High Resolution Hyperspectral Data for Stream and Riparian Habitat Analysis

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Objective: The objectives of this Hyperspectral EOCAP Project are twofold. First, the project seeks to test the application of airborne hyperspectral imagery to riparian and in-stream ecological and environmental studies and monitoring. Second, using experience gleaned from these application tests, we are defining the unique and common requirements of hyperspectral data for operational commercial and scientific uses in the area of stream and habitat analysis.

Findings: Our results fall into these two broad categories: specific stream study application results and more general conclusions about commercial hyperspectral data requirements. We are documenting which specific stream ecology variables can best be measured from airborne hyperspectral sensors, and which stream parameters are not amenable to hyperspectral determination. Through acquisition of the field and airborne data, development of experimental protocols, analysis and processing of the hyperspectral data and documentation of the results we are building the case for stream and riparian studies using hyperspectral data. Furthermore, we are discovering, often through the process of trial-and-error, numerous critical gaps and deficiencies that exist in current systems that hinder the commercialization of hyperspectral data for riparian studies.

In 2001, hyperspectral data sets collected in 1999–2000 1–m, 5–m, and 8–m Probe-1 (128 channels) and 2–m and 17–m AVIRIS data (224 channels) were analyzed. Extensive ground-truth data were collected along the Soda Butte and Cache Creek study sites. Six main classes of ecological parameters that we seek to study and classify are: 1) stream morphological units, 2) steam Departmenth and flow regime, 3) substrate particle size, 4) in-stream algae chlorophyll levels, 5) woody debris, 6) heavy metals and associated mine tailings in fluvial sediments, and 7) riparian vegetation community mapping including individual species identification of willow, sedge, cottonwood, aspen, upland grasses, rushes, alder, sagebrush, and conifer species.

These six main classes of variables span the range from relatively easy to extremely difficult, in terms of hyperspectral measurement. Each ecological variable has its own degree of hyperspectral leverage, or observability in the hyperspectral data. Furthermore, key issues such as spatial and spectral resolution, noise level, geometric fidelity, geopositioning accuracy and timeliness of data delivery and processing affect each specific application differently. Using multiple spatial and spectral resolutions, and multitemporal data sets, we are investigating and documenting the complex interplay between instrument and data parameters and the usefulness and accuracy of the derived ecological products.

While spectral contrasts exist among classes and species of vegetation, and even exist among subclasses of a single type, they are subtle and change throughout the growing season. Unlike the small spatial scale and rapidly time-varying nature of the in-stream parameters, the riparian vegetation is distributed in broader units that generally persist from one season to the next. Successful mapping of these plant species rests heavily on correlation of field spectrometry with airborne data. This particular application lends itself to a multi-temporal approach, leveraging the different spectral trajectories of the plant communities throughout the growing season. Initial investigations of the airborne data show tremendous spectral diversity in the riparian vegetation. Empirical spectral analysis indicates that more than a dozen spectrally unique vegetation classes can be mapped. Current efforts involve matching field mapping with the aircraft data results.

Throughout our EOCAP project we are focusing on our dual hyperspectral objectives: developing convincing case study demonstrations of the hyperspectral measurement of important stream and riparian ecology parameters and documenting and developing the common and unique requirements of operational systems to perform these studies in the future. Specifically, we are collecting a laundry list of needs and requirements for commercial systems for hyperspectral stream studies. This list documents specific spatial, spectral, and radiometric design requirements. In addition we are addressing the more mundane, yet critical, aspects of operational acquisition and application including the timely delivery of data and products and its long-term use and archiving. Our initial results from our first field season are very encouraging and productive, both in terms of the development of tantalizing case studies and the frustration involved with finding and documenting technology gaps and shortcomings. Final report of Phase II is now available and we are working on numerous manuscripts. As of April 1, 2002, five have been submitted for publication.

Project title: Cougar-Wolf Interactions in Yellowstone National Park: Competition, Demographics, and Spatial Relationships

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Objective: 1) Document the characteristics of the cougar population, including population size, survival, cause-specific mortality, natality; and compare results with pre-wolf data on cougar population characteristics in the Northern Greater Yellowstone Area. 2) Assess the effects of cougar predation on elk and mule deer populations as influenced by the presence of wolves. 3) Assess competition and resource partitioning between cougars and wolves by comparing species' spatial and temporal habitat use patterns and prey utilization characteristics. 4) Quantify spatial and temporal interactions between cougars and wolves. 5) Communicate research findings to state and federal agencies and the general public through annual technical reports, research updates, and presentations.

Findings: Hornocker Wildlife Institute (HWI) personnel captured and radio-collared a total of 45 cougars (March 1998 through March 2001) in and adjacent to areas used by 35–60 wolves within three packs on the Northern Yellowstone Study Area (NYSA), the Yellowstone Wolf Restoration program. Researchers associated with both HWI and Yellowstone National Park (YNP) conducted aerial and ground monitoring of radioinstrumented animals.

Field crews searched 1208.7 km to 1621.3 km (755 mi to 1013 mi) of track transect during winters 1998–2001 to conduct cougar sign surveys and provide an estimate of cougar population size. A minimum of 21–22 adult and subadult cougars was present on the NYSA during the 1998–2001 winter seasons. Fourteen resident adults (3 males; 11 females) and 9 of 11 kittens in five family groups are currently being monitored on the NYSA.

Eight adult females produced thirteen litters of 2–4 kittens resulting in 33 offspring documented during March 1998 to August 2001. Thirteen cougar deaths were documented. The deaths included all four of female F107's kittens, which were killed by the Druid wolf pack in two separate events occurring near a cow elk killed by F107. Four cougars were killed by other cougars, one died from unknown causes, one fell off a cliff while attempting to kill a bighorn sheep, one was legally harvested during the Montana cougar hunting season, and 1 cougar kitten was killed by a black bear. Thirteen cougars have dispersed to areas adjacent to and beyond the NYSA.

Weekly aerial flights were scheduled in conjunction with wolf location flights to obtain simultaneous cougar–wolf locations. Through intensive ground monitoring, we documented 202 positive and probable cougar kills. Prey included 140 elk, 38 mule deer, 2 bighorn sheep, 1 antelope, 7 coyotes, 6 marmots, 4 porcupines, 1 red squirrel, 1 blue grouse, 1 red fox, and 1 golden eagle.

A collaborative study of Feline Immunodeficiency Virus prevalence and evolution related to cougar population dynamics continued in 2000–2001. Collaborators in this study include the University of Montana, University of Wyoming, and the Hornocker Wildlife Institute. The Hornocker Wildlife Institute was also involved in collaborative studies on cougar–wolf–grizzly bear–human hunter interactions in the Greater Yellowstone Area, and cougar stress hormone detection in feces with the University of Idaho.

Project title: Multi-trophic Level Responses to the Addition of a Top Carnivore

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Objective: This study is examining the ecological changes associated with re-establishment of wolves in Yellowstone National Park in 1995 and 1996. Species representing three important trophic levels—wolves, elk, and woody vegetation—are the focus of the research. The specific areas of interest are: 1) spatial and temporal patterns of abundance of the newly introduced top carnivore (gray wolf), the dominant herbivore (elk), and woody vegetation on YNP's northern range, and 2) mechanisms underlying trophic dynamics, especially predation rate of wolves and herbivory use by elk on woody vegetation.

Findings: In 2001, 13 radiocollared elk died: 6 were taken by hunters (46% of total mortalities), 1 by a cougar (8%), 4 by wolves (31%), and 2 died of unknown causes (15%). All but one of these mortalities occurred during the winter. An additional 2 elk died due to possible capture-related complications (stress-induced myopathy).

Based on data from GPS-collared elk and also from regular VHF tracking of the collared animals, we documented the current major migration routes of the northern elk herd. Elk travel from their wintering grounds on the northern range to areas as far south as Lewis Lake, east to the eastern border of the park, and north onto the Buffalo Plateau. A small number of elk remain on the northern range even during the summer. Of those that migrated, most elk return to the winter range in mid-October through mid-November, usually in response to snowfall. Migration generally occurs along the obvious large drainages or major ridgelines.

The migratory patterns of the herd segment that summers in the Lewis Lake area were not well-known based on data from 2000, but because of our larger sample of radiocollared elk in 2001, and because of the continued aerial tracking of these animals, new information on their movements was found. These long-distance travelers migrate via the Washburn range/Carnelian Creek region and, remarkably, they can make their 70-kilometer journey between the northern range and the Lewis Lake area in less than four days. All of the elk returned to the northern range by late November, except for one of the elk that summered by Lewis Lake. This animal remained near the South Entrance as late as December 14, when her GPS collar dropped off as programmed.

A preliminary analysis of habitat selection by elk was done to compare pre-1988 fire/pre-wolf, post-1988 fire/pre-wolf, and 2000–early 2001 post-wolf periods. A herd-wide, landscape-scale model of summertime habitat selection showed elk selected for areas of higher elevation, intermediate slope, and southeast to northeast aspects. Elk also selected for grass–forb communities and burned forested areas and they selected against areas of mature conifer forest.

Comparing pre-wolf and post-wolf habitat use, the only major difference detected thus far between these time periods was that elk currently select higher elevations during the summer. This difference could be a result of elk moving to higher elevations away from high wolf-use areas while wolves are centered around their denning areas at lower elevations in the early summer period; however, it could equally be attributed to the drought conditions of the past several years. Dry climatic conditions have left relatively little forage at the lower elevations, possibly pushing elk to the cooler, moister ridgetops.

A preliminary population reconstruction effort for the northern Yellowstone elk herd resulted in minimum number alive (MNA) estimates of 10,856 elk in 1995, 10,625 elk in 1996, 8,280 elk in 1997, 7,228 elk in 1998, 5,676 elk in 1999, and 4,245 elk in 2000. The decline in these MNA estimates over time do not represent a decline in the elk population. There is simply a smaller sample of elk mortality data used for population reconstruction in years closer to the present (these numbers become more accurate with each additional year of elk mortality data).

We recommend that the NPS continue to gather data on elk mortalities caused by hunting, cougars, wolves and winterkill. Both the MNA estimates and sex–age composition of the northern herd will become more robust with each additional year of population reconstruction data.

Project title: Climatic Variation in the Greater Yellowstone Ecosystem: Evaluating the Evidence for Decade–to–Centennial Variability in Climate

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Objective: Our objective is to investigate the record of climatic variability in the Greater Yellowstone Region (GYR) to enhance our understanding of regional patterns and processes. The climate record will be reconstructed by climatically sensitive tree-ring chronologies. For example, studies of the interactions between climatic variability, fire, and grazing in regulating forest stand structure and composition will be enhanced by longer and more detailed climatic histories of the region. Similarly, research on interactions of fire, climate and geomorphic processes will benefit from better information on climatic trends and variability. Finally, long-term histories of climate can inform the monitoring strategies for assessing the impact of global environmental change on mountain regions.

Recently discovered long (1,000+ years) tree-ring records from the Greater Yellowstone Region (GYR) in the Rocky Mountains are relevant to the larger effort to understand the patterns and causes of climate variability at high elevations. The GYR is one of the few places in the world where we can develop a strongly replicated, multi-species network of long tree-ring series that are sensitive to precipitation. Interannual and decadal-scale variation in winter precipitation and snow pack in the GYR exhibits patterns that are strongly coherent with variability in the Northwestern United States. The regional snowpack anomaly patterns are, in turn, associated with regional- to hemispheric-scaled atmospheric circulation patterns. As such, a strong potential exists for using the GYR data to reconstruct 1,000+ year histories of key multi-decadal atmospheric circulation patterns such as the Pacific Decadal Oscillation.

Findings: Eight tree-ring records that extend 1,000 years and longer from the GYR were obtained from species including Douglas-fir, limber pine, and whitebark pine. Sites range in elevation from 1,740 m to 3,080 m, and are characterized as low productivity sites unaffected by fire. An abundance of remnant wood exists at these sites due to the absence of fire and an ideal climate for wood preservation. The remnant wood, when cross-dated with samples from living trees, provides chronologies that extend up to 2,200 years before present. We analyzed the climate signal in the most drought sensitive tree-ring chronology (Mt. Everts Douglas-fir; MEDF) by relating the series to modern data for winter precipitation, snowpack and stream flow at nearby observational stations. To characterize the series in the frequency domain, we applied spectral analysis using a multi-taper method with red noise assumptions to the full length of the MEDF chronology.

The correlation between the MEDF chronology and winter precipitation and associated variables such as the Palmer Drought Severity Index and April snowpack is significant and positive. Further, during the 20th century, the MEDF chronology exhibits strong decadal-scale variability similar to that of the Pacific Decadal Oscillation (PDO), notably shifts in series value at 1947 and 1977.

The full MEDF record exhibits decadal-scale variability over the full length of the record. Spectral analysis of the record (1167–1999) reveals significant peaks (>95%) centered approximately at periods of 60, 40, 28, 6.5, 2.8, and 2.3 years.

The changes in the dominant periods of decadal-scale variance in a tree-ring series that is strongly related to PDO is consistent with other recent reports of changing amplitudes of PDO over the past several centuries. Incorporating the larger tree-ring network currently under development will facilitate a more complete investigation of the changes in precipitation regimes in the GYR.

These results, although preliminary, have two important implications for our understanding of mountain climate variability. First, characterization of PDO and other ocean-atmosphere interactions based on 20th century observations does not capture the full range of these dynamics. Second, the impacts of anthropogenic greenhouse warming in mountain regions will be modulated by the impacts of PDO and other drivers of decadal-scale climate variability on winter precipitation and snow accumulation.

Project title: Ecology of Selected Habitats in Yellowstone National Park—A Wheaton College Science Station Course

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Objective: 1) Quantify vegetation species richness and density in 1988 burn and 1984 blowdown areas. 2) Evaluate the influence of thermal runoff on aquatic macroinvertebrates in streams draining geyser basins and compare to streams outside of the park lacking thermal runoff. 3) Observe adapatations of bacteria, algae, cyanobacteria, and other life to the diverse hydrothermal features of YNP.

Findings: We found densities of lodgepole pine in burned areas to be about eight times greater than those in 1984 blowdown areas that also had burned in 1988. Plant species richness was slightly greater in burn/blowdown areas than in burn-only areas. The Firehole River was substantially warmer (28°C) than a stream at a comparable elevation outside the park (Tongue River, Bighorn Mountains, 19°C), and harbored some invertebrates (e.g., amphipod crustaceans) that streams without thermal runoff did not. Both the Firehole River and Nez Perce Creek were infested with the New Zealand mud snail; infestations seemed heavier in Nez Perce Creek. At West Thumb Geyser Basin, as has been previously published, distributions of bacteria, algae, and cyanobacteria were related to water temperature, as determined by color of the microbial mats. These results are intended for educational use only and not for publication.

Project title: Browsing Phenology of Willows, Cottonwoods and Aspen on the Northern Range, Yellowstone National Park

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Objective: The objectives of this study are to determine when the woody riparian species are browsed during the winter and to determine if it occurs as a short-term episode or as a continuous process during the course of the winter. This information will be correlated with climate to look for climate-browsing interactions. We are recording only the cumulative percent of stem tips browsed and not the percent of current annual growth taken.

Findings: Each year has followed a pattern of browsing. Early in the season there has been very light browsing, which we interpret as exploratory, followed by a short period of more intense browsing, terminated by a complete taking of at least the current year tips. This has occurred generally between late December and late January to mid February.

The timing of these events has varied geographically, between species and between years. At sites where both willows and aspen or willows and cottonwoods occur, the willows have been eaten earlier than the other two species.

Project title: Landscape Use by Elk During Winter on Yellowstone's Northern Range

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Objective: The objectives of this study were to document winter patterns of landscape use by Yellowstone northern range elk, measure elk feeding activity (as indexed by number of feeding craters), quantify snowpack characteristics, and examine how these and other landscape and habitat features influence elk foraging locations. How does snow affect the distribution of elk during winter on Yellowstone's northern range? What other factors, such as winter temperature, forage, and predator/prey density, affect their distribution?

Findings: We measured site and snowpack characteristics, elk (*Cervus elaphus*) feeding crater densities and morphometry, and elk numbers in the Lamar River Valley and the Blacktail Plateau on the northern range. We conducted the study over three winters, 1992–1993 to 1994–1995, but the main sampling effort occurred over four monthly sample periods in year one. Snow Departmenth, snow water equivalent (SWE), and snow resistance to horizontal movement and vertical penetration all increased steadily over the winter. The mean (SD) feeding crater diameter and Departmenth was 118 (37) cm and 34 (11) cm, respectively, and both were positively correlated with snow Departmenth. The mean (SD) crater volume was 385 (321) l, and the mean (SD) mass of snow excavated from a crater was 82 (72) kg. Non-woody plants (grasses, sedges and forbs) were the primary browse item in 90% of the craters. The highest aerial elk counts were observed in early- to mid-January, and counts declined substantially and steadily after January 29. At this time, mean snow Departmenth was about 50 cm and mean SWE was about 12 cm. The mean number of new craters on a plot showed a significant, negative association with snow Departmenth, SWE and booted-foot sinking Departmenth. We used the sum of craters on a plot across all four sample periods as an index of winter long feeding activity. Elevation and habitat type were the best site characteristics for differentiating plots in regard to winter-long use. Summed craters were negatively associated with elevation, and the habitat type with the highest summed craters was tufted hairgrass/sedge. Only about 5% of plots that had craters had areal crater coverage in excess of 14%, with a maximum of 23% coverage, suggesting that snow disturbance associated with cratering activity may inhibit elk foraging. We are preparing manuscripts for publication and are also preparing for field work starting November 2002.

Project title: A Landscape Approach to Aspen Restoration: Understanding the Role of Biophysical Setting in Aspen Community Dynamics

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Objective: Widespread loss of aspen stands in the western United States has been well documented. Valued as a keystone species, aspen communities are critically important to maintaining biodiversity, soil quality, and nutrient cycling. Fire suppression, ungulate herbivory, and climatic change are the most widely advanced explanations for the decline of aspen. The role of biophysical factors (e.g. topography, climate, soils, competitive interactions), in governing aspen performance, however, is poorly understood. To better understand the influence of biophysical variables on aspen dynamics, this study addresses the following three hypotheses: 1) the aerial distribution of aspen is not random across the landscape and varies as a function of biophysical setting. 2) Within its distribution, growth rates and productivity of aspen stands differ relative to biotic and abiotic variables. 3) Rates of aspen loss in the landscape differ relative to biophysical setting.

The study area is the Greater Yellowstone Ecosystem from a southern boundary near Jackson, Wyoming. The study area includes areas of Yellowstone National Park, the Gallatin National Forest, Targhee National Forest, Bridger–Teton National Forest, and Grand Teton National Park. Analysis to date is restricted to the Gallatin National Forest and Yellowstone National Park, and addresses the first two hypotheses.

Findings: Preliminary analysis of aspen distribution involved mapping the distribution of aspen across the study area (currently Gallatin National Forest and Yellowstone National Park) and using classification and regression tree analysis (CART) to examine the relationship between environmental variables and aspen distribution. Aspen distribution was obtained from aerial photograph interpretation and GIS data from the Gallatin National Forest stand cover map and Yellowstone National Park cover-type map. Predictor data used were elevation, slope angle, aspect, and soil parent material. Hold-out data showed that the resulting CART model accurately predicted aspen occurrence 91.2% of the time; however, mapping the model across the landscape showed over-prediction of aspen occurrence. We plan to expand our study area to include the southern end of the ecosystem and include climatic predictor variables and more specific soils predictor data.

Aspen performance relative to biophysical setting is being examined through field measurement of aspen stand structure, composition and growth rates. We sampled 47 sites in the Gallatin National Forest and Yellowstone National Park (eight sites in Yellowstone were sampled) during the 2001 field season. We used a nested, circular plot design to measure tree density by species and dbh class, seedling/sapling density, herbaceous biomass, shrub density, canopy cover, and density of course woody debris. We also took increment cores of aspen trees of each dbh class represented on a site.

Analysis of field data is in the preliminary stages. Using BIOPAK software, we have calculated biomass estimates for shrubs and trees by species. We will be using increment cores to estimate current and past aspen biomass and obtain annual change in above–ground biomass. We will regress this measure of aspen productivity against abiotic (topographic, soils, and climatic) and biotic (herbaceous biomass, shrub biomass, and tree biomass by species) variables to examine any relationship between aspen annual net productivity and biophysical environment.

Project title: Medium-Sized Carnivore Project

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Objective: 1) Assess several methods to inventory and monitor medium-sized carnivores: weasels, otter, wolverine, marten, fisher, lynx, bobcat, mountain lion, fox, coyote, and gray wolf. 2) Examine various habitat and landscape characteristics related to their presence/absence. 3) Conduct presence/absence surveys in

Yellowstone National Park and surrounding wilderness areas. 4) Evaluate long-term changes in presence/absence detection trends.
Findings: With the notable exception of three decades of research on grizzly bears, and more recent studies on mountain lions, pine marten, and coyotes, we know very little about Yellowstone's mammalian carnivores. Members of the order Carnivora are typically secretive, nocturnal, and exist at low population densities. In many cases, we do not even have reliable methods to determine presence, let alone estimates of abundance and other important demographic parameters. During the winters of 1990 through 1997, we conducted detection surveys and evaluated three methods: hair snares, remote camera stations, and snow track transects. Their utility as estimates of presence, distribution, and abundance were evaluated, as well as their cost, maintenance, reliability, precision, and bias. Response to hair snares and camera stations were variable locally and between years. Hair snares have the exceptional advantage of providing DNA and potentially identifying individuals, but has the disadvantage of relatively high maintenance and cost and provided unreliable results from the analysis of hair characteristics. Camera stations, like hair snares, performed well in adverse weather and can identify individuals, but suffer from avoidance bias by several resident species. Camera stations were costly in terms of expense and maintenance. Snow track transects identified four species not detected by other methods and were simple, low cost, and low maintenance. They provide precise habitat information, whereas camera stations and hair snares are baited with food and scent lures which bias results concerning habitat use. Snow track transects allow researchers coverage of large areas and habitat types and can provide valuable information if scats are found and if DNA is successfully extracted. The reliability of species identification from snow track transects is a major disadvantage due to poor climatic conditions and the similarity of many species' track characteristics. Although the specifics of objectives and logistics should dictate use of these methods, we suggest a variable combination of all three methods for determining presence and distribution. All methods have significant problems, especially when inferring abundance. Determining relative habitat use from snow track transects proved reliable and matched that known from previous studies. This project resulted in the confirmation of fisher in the Yellowstone ecosystem. Efforts in 2001 focused on continuing detection surveys across the northern range. All survey routes were covered twice (once early and once late) during the winter of 2001–2002. Further analysis of data and preparation of manuscripts for publication will proceed.

Project title: The Ecology of Arbuscular Mycorrhizae in Yellowstone's Thermal Areas

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Objective: *Arbuscular mycorrhizae* (AM) are a plant–fungus symbiosis, in which the plant provides the fungus with a carbon source, while the fungus increases plant fitness via enhanced nutrient availability (especially phosphorus) and water acquisition, and protection from pathogens. Fossil evidence has shown the presence of mycorrhizal fungal structures associated with the first land plants. The early existence of this relationship suggests that mycorrhizae are significant in the evolution of terrestrial plants. In addition, approximately 95% of extant plant species are estimated to be mycorrhizal; therefore, we cannot thoroughly understand plant response to environmental stress gradients without simultaneously examining the mycorrhizal symbiosis.

The role of AM in Yellowstone's thermal areas has not been studied and is difficult to predict, especially across the existing environmental gradients. Mycorrhizae might augment plant growth in a broad range of environments for numerous host and endosymbiont species. However, they have also been shown to decrease growth in situations where the cost of carbon allocation to the fungus exceeds the benefits of the symbiosis. In these high-stress environments where carbon fixation and biomass accumulation are limited, the mycorrhizal symbiosis might function differently than in environments that are more amenable to plant growth.

With this research we will 1) assess the distribution of AM fungi across environmental gradients at geothermal sites, 2) measure the effects of AM on plant growth in thermal-influenced soils, 3) determine whether AM fungi isolated thermal sites are better adapted to maximize mycorrhizal benefits to host plants growing in extreme conditions than fungi from non-hydrothermal sites, and 4) increase our understanding of this plant/fungal interaction in extreme environments, such as the high temperature, extreme pH, and low nutrient sites found adjacent to thermal sites in Yellowstone.

Findings: In summer 2000, we sampled plant roots from five sites including Hundred Springs Plain in the Norris Basin, Amphitheater Springs, the Firehole River near Ojo Caliente, and Rabbit Creek. Plants from these sites, growing in soils with rooting zone temperatures up to 480°C, and soil pH values down to 3.4, were mycorrhizal, with colonization levels ranging from 2 to 54%. Mycorrhizal fungal propagules were 77% less abundant in geothermal-influenced soils as compared to soils from well-vegetated areas.

In the summer and fall of 2001 we examined mycorrhizal colonization levels of *Agrostis scabra*, *Dichanthelium lanuginosum*, and *Mimulus guttatus* across thermal and soil pH gradients during June, July, August, and October. *Mimulus guttatus* was sampled in June, but had senesced by July. *Agrostis scabra* was first identified and sampled in July, and had senesced by August. *Dichanthelium lanuginosum* was sampled each month. Overall colonization of the plants did not vary significantly by month, soil chemistry, or soil temperature. However, the percentage of arbuscules present in the *Dichanthelium lanuginosum* roots decreased from June through August and then increased slightly in October (ANOVA; $F=3.114$, $p=0.036$).

We conducted a greenhouse experiment to assess the effects of mycorrhizae on *Dichanthelium lanuginosum* and *Agrostis scabra* plants growing in elevated rooting temperatures (400°C). Plants were grown in three soils: sterilized, sterilized with native microbial community, and nonsterilized (mycorrhizal). Comparisons presented are made between the latter two soil treatments because these isolate the effect of AM fungi from the rest of the soil community. *Agrostis scabra* plants were smaller when grown with mycorrhizae in both ambient and elevated rooting temperatures, suggesting that the cost of AM exceeded the benefits in these soils. *Dichanthelium lanuginosum* was smaller when growing with mycorrhizae in ambient temperatures, but equal in size when grown in elevated temperatures. However, a significant increase in shoot biomass was observed in mycorrhizal plants, that was most pronounced when grown in elevated temperatures. Plants with more above–ground biomass also have more leaf area, thereby increasing photosynthetic ability and, potentially, overall fitness. For *Dichanthelium lanuginosum*, mycorrhizae shifted from detrimental to beneficial as the environmental stress (here elevated rooting temperature) increased.

Our current greenhouse experiment addresses objectives 2 and 3 concomitantly by examining the effect of acidic and alkaline soil water on the mycorrhizal symbiosis in *Dichanthelium lanuginosum*, *Agrostis scabra*, and *Mimulus guttatus*, and the possible adaptation of AM fungi to their native environment. The greenhouse experiment is complete factorial and includes four mycorrhizal treatments (a control with no AM fungi, and AM fungi added from an acidic thermal soil, an alkaline thermal soil, or a non-thermal soil) and three pH treatments. Plants are watered with dilute nutrient solutions of pH 3.5 (altered using H2SO4), 6.5 (unaltered), and 9.5 (altered using NaOH). Preliminary analysis suggests that both the mycorrhizal source and pH have significant effects on the fecundity of *Mimulus guttatus* and the height of *Agrostis scabra*, supporting our hypothesis that mycorrhizal function is dependent on environmental conditions, and that AM fungi from extreme environments function differently than AM fungi from non-thermal soils.

Project title: Specificity in Ectomycorrhizal Symbioses

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Objective: To Determine how above–ground disturbances, such as natural fire, foliar diseases and defoliation, and litter manipulations, affect structure and function of below–ground microbial communities.

Findings: Litter addition: In this study, we used molecular–genetic methods to determine effects of litter addition on the EM community of a *Pinus contorta* stand in Yellowstone regenerated after stand–replacing fire. Results indicate that 1) species richness did not change significantly following perlite addition (2.6 +/- 0.3 species/core in controls, 2.3 +/3 in perlite plots), but decreased significantly (P<0.05) following litter addition (1.8 +/- 0.3), 2) EM infection was not affected by perlite addition, but increased significantly (P<0.001) in response to litter addition; this increase occurred only in the upper soil layer, directly adjacent to the added litter, and 3) Individual EM fungal species reacted differently to each treatment type.

Defoliation: Molecular genetic methods were used to determine whether artificial defoliation affects ectomycorrhizal (EM) communities. All lodgepole pines in three replicate plots were defoliated 50%, while Engelmann spruce were left untreated. This was done to determine how defoliation of one conifer species would affect EM mutualisms of both treated and neighboring, untreated conifers. Results indicated no significant effect on either EM colonization (142.0 EM tips/core in control plots and 142.4 in treatment plots), or on species richness (5.0 species/core in controls and 4.5 in treatments). However, the relative abundance of EM of the two tree species shifted from a ratio of approximately 6:1 without treatment (lodgepole EM: spruce EM), to a near 1:1 ratio post-treatment. In addition, EM species composition changed significantly post-defoliation. Furthermore, species of EM fungi associating with both lodgepole pine and Engelmann spruce were affected, indicating that alteration of photosynthetic capacity of one species can affect mycorrhizal associations of neighboring non-defoliated trees.

Litter removal: Three treatment/control blocks were established comprising three treatment plots in which all litter was removed. Results of soil analyses indicate significant decreases in total nitrogen (0.22% total nitrogen in controls and 0.18% in treatments) and ammonium (6.6 ppm in controls and 4.8 ppm in treatments) following litter removal. Results of molecular analyses indicate that 1) litter removal significantly decreased EM fungal species richness, from 3.0 to 1.5 species/core; 2) as expected from previous studies that indicate that increased nitrogen in litter can inhibit EM infection, litter removal induced a significant increase in EM infection, from a mean of 228 EM/core in controls to 326 in treatments; 3) the ratio of basidiomycetes to ascomycetes changed significantly in response to litter removal, from 12:1 ratio of basidiomycete to ascomycete EM, to a 3:1 ratio.

Project title: Multifactor Controls on Persistence of Willows: Quantitative Assessment and Anaylsis of Factors Contributing to Variable Herbivory Levels Pre-1995 and Post-1997

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Objective: To determine whether willows have been released from their browsing–induced suppressed state as a result of lower elk populations following reintroduction of wolves to Yellowstone National Park.

Findings: At this point, several northern range willow stands and tagged willows from studies conducted by F.J. Singer in the late 1980s have been relocated and measured for productivity during August 2001. These stands will be revisited in April 2002 to be examined for winter offtake levels by ungulates. Additionally, several stands that are further in the backcountry from the northern range will be located and measured as well. These stands will also be measured for a second year of productivity in August 2002.

Project title: Ectomycorrhizae of Thermal Soils

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Objective: To determine microbial community structure and function in low pH thermal soils.

Findings: Molecular methods and comparisons of fruiting patterns (i.e., presence/absence of fungal fruiting-bodies in different soil types) were used to determine ectomycorrhizal associates of *Pinus contorta* in soils associated with a thermal soil, classified as ultra- to extremely acidic (pH 2–4). Ectomycorrhizae were sampled by soil core (36 total) from six paired plots of three cores each, from both thermal soils and forest soils directly adjacent to the thermal area. Fruiting–bodies (mushrooms) were collected for molecular identifications, and to compare fruiting–body (above–ground) diversity to below–ground diversity. Results indicate 1) significant decreases in both EM infection (130 SE 22 EM root tips/core in forest soil, 68 SE 22 in thermal soil) and EM fungal species richness (4.0 /- 0.5 species/core in forest soil, 1.2 SE 0.2 in thermal soil) in soils associated with the thermal feature, 2) that the EM mycota of thermal soils was comprised of a small set of system dominants, with very few rare species, while that of forest soils contained a few dominants, with several rare EM fungal species, 3) *Dermocybe phoenecius* and a species of *Inocybe* which was rare in forest soils, were the dominant EM fungal species in thermal soils, 4) that aside from this single *Inocybe* species, there was no overlap in the EM fungal communities of forest and thermal soils, and 5) the fungal species forming the majority of the above–ground fruiting structures in thermal soils (*Pisolithus tinctorius*, commonly used in remediation of acid soils) was not detected on a single EM root tip in either soil type. Thus, *P. tinctorius* may be fulfilling a different role in these thermal soils. This indicates that this species may not perform well in remediation of all acid soils, and indicates the relationships among factors such as pH, soil temperature, and soil chemistry in influencing EM fungal community structure. In addition, at least one new species with potential for use in remediation of hot acidic soil is indicated.

Project title: The Living Stream

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Objective: Course was not taught in 2001

Findings: None. The course will be resumed in 2002

Project title: Persistance of Willow in Yellowstone National Park: Interactive Effects of Climate, Hydrology and Herbivory

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Objective: The focus of our study is to tease apart the influences of hydrology and herbivory on the growth and reproduction of willows *(Salix* spp.*)* on the northern range of YNP. Willows have declined in the northern range over the last 100 years, and potential driving factors include a recent increase in elk *(Cervus elaphus)* and a decline in water tables, due to a decline in beaver *(Castor Canadensis),* and/or a drying climate. We will use an experiment, a study of willow dendrochronology, and a modeling exercise to address how these factors may influence willow survival. We will also examine historic beaver occupation in the park in order to gain insight into the role of beaver in willow establishment.

First, we are conducting a field experiment with two treatments: herbivory reduction (by exclosing large herbivores), and water table elevation (by inhibiting the velocity of small adjacent streams). The experiment is fully factorial, meaning that each site consists of four plots: an exclosed and water–elevated plot, an unexclosed and water–elevated plot, an exclosed and water–normal plot, and a control plot. We are replicating this design four times at the site level in order to obtain enough statistical power to determine the relative influences of the treatments and any potential interactions. We will measure the response of three willow species *(S. geyeriana, S. bebbiana,* and *S. boothii)* by measuring current annual growth, plant height and volume, seed production, water stress (by measuring C13 concentrations of leaves), and groundwater utilization (by comparing isotopic signatures of groundwater vs. xylem water).

Second, we will conduct a study of willow ages and ring widths in order to address willow establishment and to expand the temporal and spatial scope of the study. Comparison of willow ages and ring widths with elk population data, climate data, and historical records of beaver ponding will allow an analysis of the relative importance of herbivory, climate, and beaver presence to willow growth and establishment over the past 50–100 years. Aging of willows will take place in areas of documented beaver damming and will allow us to determine if the timing of willow establishment coincides more closely with damming or with periods of reduced elk. We will also examine growth patterns of willows in areas where beaver ponds have likely not been historically present (i.e. groundwater discharge zones and large streams) to differentiate the effects of climate and elk population on willows growing in other hydrologic environments.

Because beavers may be instrumental to willow survival and their historic presence in the Park prior to the 1800s is not well documented, we will conduct two studies to determine their historic presence in the park. First, we will examine stratigraphic cross-sections of stream floodplains to date beaver pond deposits. Pond deposits will be identified using sediment grain size analysis. Second, in order to extend the spatial extent of the study (since streams migrate and beaver don't always build dams in the same spot), we will conduct a dendrochronological study of floodplain conifers to look for evidence of ponding in the ring record. Calibration of the trees' sensitivity to ponding will be done by selecting a set of trees that are various distances from known historic beaver pond margins. These tree rings associated with stream flow conditions will be compared to long-term regional tree ring series to look for correlation with climatic patterns.

The final stage of our project will consist of modeling willow survivorship using an existing ecosystem model, SAVANNA. Results from the experiment and correlative studies will be used to refine parameters of the model so we can better predict willow growth and survivorship over the northern range.

Findings: 2001 was our first field season and most of the time was spent selecting sites and installing exclosures, water wells, and velocity inhibitors for our field experiment. All eight exclosures, all eight stream velocity inhibitors, and the majority of the ground water monitoring wells were installed. Water table measurements taken before and after velocity inhibitor installation indicate that we have successfully raised the water table by an average of 39 cm across the experimental plots (based on limited post-treatment measurements). We also took pre-treatment data on the willows in our study, tagged them, and precisely surveyed their locations. Because pre-treatment water table levels vary across and within plots, we conducted a preliminary analysis of our baseline data in order to determine what percentage of existing variation in willow growth can be attributed to Departmenth to water table. Each plant's maximum water table Departmenth was determined by interpolating water well data, and the resulting data was used in a simple linear regression analysis. We found that water table Departmenth accounts for 28% and 17% of naturally occurring variation in plant volume and current annual growth, respectively, for *S. bebbiana*. Initial water table effects were much less explanatory for the other two species. These results indicate that it will be helpful to use our pre-treatment water table measurements as a covariate in later analyses to reduce the noise in our data caused by naturally occurring variation in willow growth and size.

We also began our work on the history of beaver occupancy in YNP. A probable pond deposit on Elk Creek, 1.7 m below current floodplain level, yielded a date of 900–1160 AD.

Project title: The Behavioural–Ecological Role of Wolf Howling

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Objective: Wolf howling is one means of social coordination in wolf packs, one way that helps packs function as biological units. This study is design to test the extent to which the forgoing statement is true. To qualify, howling must: be shown to alter behavior of the pack or individuals in the pack, and that alteration must assist pack fitness by helping it accomplish a task of biological necessity such as procurement of food, raising young, defending territory.

The packs at Yellowstone offer an opportunity to compare the use of howling in packs whose unfolding history is, and will continue to be known. While many factors undoubtedly contribute to individual and group success, these packs may provide information on differences in their use of howling.

Hypothesis 1: Howling plays a role in group cohesion. Prediction: 1) There will be more howling in both the season of highest group cohesion (most pack members together or close to one another), and the pack that shows the highest cohesion.

Possible outcomes: Howling high when cohesion high, and howling low when cohesion low. (Not a definitive outcome because other factors could be responsible.) Howling high when cohesion low, or vice versa. Disproves hypothesis. 2) There will be a set of observations of cases where howling of distant pack members brings them together, versus a set of observations where howling does not bring them together. 3) Howling will be more frequent when some pack members are known to be absent versus all present, or when alphas are absent.

Hypothesis 2: Howling acts to coordinate pack movements. Prediction: There will be a set of observations of wolves bringing pack members together either when the pack is travelling, or to initiate travel, or at a kill or rendezvous site or den.

Hypothesis 3: Howling acts to identify pack members to each other versus non-pack members. Prediction: Set of observations of: wolf howling as wolf comes in to rendezvous site, den, or kill where the rest of the pack is present; ambivalent behavior of approaching wolves broken with a howl (pack members show acceptance, non-pack members show avoidance); packs near each other, or aware of each other, separate more after a howl.

Hypothesis 4: Group howling aids in social bonding/social partitioning. Prediction: Set of observations associated with play or group social display (before play or to initiate it, part of it, terminate a bout of it) or when pack members arrive or leave the rest of the pack.

Hypothesis 5: Howling aids in territorial defense. Prediction: 1) Sets of observations of packs aware of each other, howling (versus packs not howling). 2) Group howling more common (howls per minute of observation) at kills near territorial boundaries than distant.

Data: Rick McIntyre's notes will be a primary source of data. Many of them are on computer and so can be word-searched. Secondarily, we will add field observations when feasible. Obtaining data of this kind can only be done opportunistically, not experimentally (no stimulus from the researchers), a drawback of the study but one that is accepted.

Sound analysis: When possible, we will record howls with the intent of conducting computer-based sound analysis to look for features that are context-specific.

Findings: We were in the field from October 23 until October 27. Our mission was to record as many context specific howls as possible, and note occasions when howling occurred or when behavior that might have elicited howling did not do so.

During this period, portions of the Druid Peak pack were almost continuously visible during daylight hours at their traditional rendezvous site. We observed howling on 10 occasions, and recorded it nine times. Three of these howls were of a single wolf. The other recordings were of group howls. Group howls from the rendezvous site took place at crepuscular times, morning and evening. All of these howls were preceded and followed by group social interactions, but none involved movement of wolves into or from the rendezvous site. One group howl, before daylight, was from part of the pack travelling between the rendezvous site and a kill located 5.2 km away.

The single howls were from a yearling or pup that howled from Soda Creek–Lamar River junction while other members of the pack howled from the rendezvous site. They could hear each other. Nonetheless, the single wolf howled repeatedly, without going towards the rendezvous site, then took off running up Soda Butte Creek valley and was recorded or heard howling repeatedly, as we advanced too, for a distance of eight kilometers. Clearly this was an agitated wolf, and subjectively it appeared to try to attract attention to itself, then when it failed, proceeded up the valley at a very fast rate with an obvious purpose. Its howls, which are of a quality suitable for sound analysis, broke downward and upward in pitch repeatedly, but between these breaks held reasonably steady notes as is characteristic of the Yellowstone wolves (in contrast to Algonquin wolves).

On two occasions, wolves returned to the rendezvous site with no howling, although there were greeting ceremonies. On both of these occasions, the alpha animals were among the returning wolves. On one occasion, all or most of the pack left the rendezvous site, at dusk, without howling (there had been a group howl 30 minutes earlier, but after it, most of the wolves had bedded, so the howl may not have been associated with the subsequent movement).

Besides the forgoing observations and recordings, we discussed the howling project with Rick McIntyre whose field notes are important to the project, and reaffirmed the cooperative nature of the venture.

Project title: Breeding Strategies of the American Elk

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Objective: Animal behavior is often optimized as a trade-off between survival and reproduction. During the breeding season, mammals tend to maximize their effort in reproduction within the constraints of predation pressure. When predation pressure is reduced, greater effort can be allocated to reproductive behavior and less in vigilance and predator avoidance. The objective of this study was to test the hypothesis that elk in Yellowstone National Park (YNP), a predator–rich environment, would spend more time in vigilance and risk–avoidance behavior than would elk in Rocky Mountain National Park (RMNP), a predator–free environment.

Findings: Cow elk in YNP spent more time in vigilance and less in foraging during activity periods than did cows in RMNP. Also, elk in YNP retreated to forested cover during the midday inactive period whereas elk in RMNP remained in open habitat. Vigilance was not correlated with group size at either site. Cows with calves spent more time in vigilance and less in foraging than did cows without calves. Elk at Mammoth Hot Springs, a predator–free area of YNP, behaved similarly to those at RMNP. Bull elk spent more time foraging and less time in courtship at RMNP than at YNP, however these results are based on small sample sizes. Mean harem sizes were similar among the three sites, 17.0 at RMNP, 15.2 at YNP and 16.7 at Mammoth Hot Springs. The proportion of cows with calves was significantly lower at YNP (0.10) than at RMNP (0.24) or Mammoth (0.33). Elk in predator–rich areas of YNP apparently adjust their behavior to decrease predation risk

Project title: Determining Forage Availability and Use Patterns for Bison in the Hayden Valley

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Objective: 1) Determine seasonal bison habitat use patterns and factors that influence these patterns in the Hayden Valley of Yellowstone National Park, 2) identify interactions between bison and vegetation, 3) develop a monitoring strategy to track changes in vegetation due to ungulate herbivory, and 4) provide baseline data for models of ungulate-vegetation relationships in the Hayden Valley.

Findings: Data collected during 1998–2000 was analyzed. Field work was limited to tests of equipment/imagery accuracy. Estimates of forage available on a pixel basis were calculated from LANDSAT imagery and these data were made available to modelers. Preliminary models of forage production and use were created. We are securing the set of satellite images needed for estimating biomass for three summers and have completed preliminary analysis of forage offtake from cage sites. Remaining work includes spatial rectification of all satellite images, creation of a fine–scale cover map for the Hayden Valley, and integrating bison herd locations from other studies with our time–specific biomass estimates.

Project title: How Do Disturbance–Generated Patterns Influence the Spatial Dynamics of Ecosystem Processes?

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Objective: Our studies following the 1988 Yellowstone fires demonstrated that succession was surprisingly more variable in space and time than even current theory would have suggested, and that initial spatial patterns of disturbance may persist to produce long-lasting changes in vegetation. Our focus now is on explaining the spatial and temporal patterns of succession and understanding how these patterns influence ecosystem function. As part of extensive, long-term research on the causes and consequences of fire in the Greater Yellowstone Ecosystem, we are studying the spatial and temporal dynamics of nutrient cycling in areas of Yellowstone's subalpine plateau that have burned in 1988 and 1996, as well as a chronosequence of stands that have not burned for many years.

We are addressing several questions: 1) Do the enormous differences in postfire tree density produce differences in carbon and nitrogen availability across the landscape? Or, is nutrient availability governed largely by broad–scale (i.e., 10's of km) abiotic gradients (e.g., climate, substrate) and/or fine–scale (i.e., < 10 cm) heterogeneity in resources or the microbial community, such that nutrient variability is not sensitive to the spatial variation in plant community structure? 2) Does the disturbance–created mosaic leave a persistent functional legacy? What mechanisms in vegetation development may contribute to convergence (or divergence) in ecosystem structure and function across the landscape as succession proceeds? 3) How does the spatial pattern of coarse woody debris vary across the post-1988 landscape, and what is the importance of this variation for ecosystem function? Are patterns of coarse woody debris abundance related to both prefire stand structure and postfire sapling density? 4) Does the spatial heterogeneity of processes such as ANPP, nitrogen mineralization, and decomposition change with time since fire? How quickly do spatial patterns in processes develop following a large fire?

Findings: This particular component of our study was initiated during summer of 2001, although we continued monitoring some of our long-term plots in the 1988 fires. Most of our 2001 field data collection, however, was focused in the Grand Teton National Park, where fires burned during the summer of 2000.

Project title: Developing Effective Ecological Indicators for Watershed Analysis

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Objective: Natural resource extraction, other human activities, and natural perturbations such as fire have altered most watersheds throughout the Rocky Mountains. The level of alteration of these watersheds might be an important factor influencing the integrity of streams and associated riparian ecosystems that are affected by the nature of the runoff from the watershed. If stream and riparian systems are altered by watershed outputs, then characteristics of these systems might be useful as indicators of the watershed condition.

This study is designed to develop improved indicators and innovate techniques for assisting and monitoring ecological integrity at the watershed level in the western United States. Its specific objectives are to develop practical, scientifically valid indicators that 1) span multiple resource categories, 2) are relatively scale independent, 3) address different levels of biological organization, 4) can be rapidly and cost-effectively monitored by remote sensing, and 5) are sensitive to a broad range of anthropogenic and natural environmental stressors.

This study, using tributaries of the Upper Yellowstone River and their watersheds as study areas, is based, in part, on the hypothesis that streams and riparian areas often reflect the ecological integrity of the associated watersheds. Due to a funnel effect, these areas are the accumulation zones of environmental disturbances occurring in the watershed.

Identification, assessment, and validation of effective indicators will involve integration of results from research at various scales, including 1) analysis of hyperspectral and traditional multispectral imagery from both aerial and satellite platforms, 2) field surveys of stream morphology and riparian habitat, 3) analysis of remote sensing of stream and riparian attributes to assess indicators, and 4) intensive site-specific stream sampling of macroinvertebrate communities to validate the effectiveness of these indicators in assessing the watershed condition. Use and evaluation of remote sensing technologies in conjunction with ground sampling is the primary research methodology. Selection of appropriate indicators will be influenced by their ability to be monitored by remote sensing. Research on indicators first requires an understanding of the processes and components that create the system from which indicators are selected. Only after this understanding can truly functional indicators be selected. This project is guided by this principle.

Findings: 42 watershed parameters, including levels of landscape alteration, have been identified with LANDSAT Stream geomorphic measurements and have included morphological units, determination of woody debris, morphometrics. However, this relationship is not site specific, but is a system-wide state. Riparian indicators are being selected through use of several multivariate analysis techniques. Riparian community factors are closely related to watershed parameters. Aquatic ecological variables are being used to validate the relative pristine or altered nature of the watershed. Variables include water chemistry. Remote sensing hyperspectral imagery data have been made available to this project from a NASA project in YNP to allow early evaluation of its potential for identifying possible indicators. Initial analyses show that it can distinguish between several stream physical parameters, such as pools and riffles.

Future work on this project will include limited collection of field data to fill in data gaps identified during early data analysis. More comprehensive, integrated forms of multivariate analyses will be used with combined stream and riparian data. Hyperspectral imagery flights in summer 2002 will generate images to evaluate the potential of remotely sensing indicators identified through multivariate analysis. Aquatic samples collected in summer 2001 will continue to be analyzed, along with limited summer 2002 samples, to designate levels of significance of alteration of project watersheds.

Project title: Study of the Effects of the 1988 Wildfires on Yellowstone Stream Ecosystems

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Objective: This project examines the processes of stream ecosystem recovery after a large-scale disturbance (fire), while also examining the cumulative effects of a natural disturbance on an entire watershed (Cache Creek, YNP. Changes were monitored in the chemical properties of water, physical habitat conditions, and in the structure of biotic communities that included primary producers (algae) and secondary consumers (macroinvertebrates). These results also will be used in conjunction with data from the previous 13 years to determine mid-range effects of wildfire on stream ecosystem recovery. We also are examining the difference between natural and anthropogenic disturbances to stream ecosystems by comparing stream ecosystem recovery after the 1988 fires in YNP with stream ecosystem recovery after anthropogenic disturbances such as logging and livestock grazing in stream watersheds outside Yellowstone National Park's northern boundary in Montana.

Findings: Chemical: Specific conductance ranged from 60 mS/cm in the uppermost Cache Creek 2nd order location to 252 mS/cm at the lowermost Cache Creek 4th order location over the past two study years. As is expected, specific conductance increases downstream and is highest in the larger streams. Alkalinity is a measure of the carbonate content of stream water. Alkalinity like specific conductance increased from upstream to downstream. Cache Creek sites had alkalinity ranging from 34 mg CaCO3/L to 114 mg CaCO3/L at the furthest downstream site. Alkalinity at the Cache Creek sites and the Montana Big Creek watershed were lower than the remaining comparable streams. Hardness is a measure of calcium and magnesium ions, which are usually the principal cations in solution. Hardness values were higher overall in the 2000 sampling dates. Hardness values only slightly increased as sampling continued downstream, however all fourth order streams had higher hardness values than lower order streams. The pH for all streams ranged from 7.11 to 8.61 all within acceptable aquatic biotic limits.

Physical: Discharge did not always increase downstream as is typical. This may be indicative of subsurface vertical and lateral flow. The year 2000 was a record low water year in YNP and presumably in the

Montana sites as well. Hydraulic slope was higher at lower order streams and tributaries in the groupings and lowest in the higher order streams.

Mean bankfull width, mean baseflow Departmenth, mean particle size, and percent embeddedness were calculated for each stream system. Bankfull width and Departmenth increased with increasing stream order. Both Cache Creek 4th order sites had smaller mean baseflow Departmenth than the 3rd order sites which would influence the smaller discharge values for those sites. Mean particle size is a first step in substrate analysis and further analyses should be done to test for differences in substrate heterogeneity.

Biological: Overall mean periphyton chlorophyll a was higher in the smaller order streams. However, the Tom Miner Creek./Horse Creek grouping and the Mill Creek/Lion Creek grouping had two to six times more chlorophyll a per mg/m2 than all the other streams. Perhaps these watersheds are nutrient enriched when compared to similar watersheds in the surrounding area. However, this conclusion is not supported by the total dissolved solids content of the water as indicated by the specific conductance values. At a finer resolution there appears to be no relationship between the amount of chlorophyll a and upstream, tributary, or downstream placement. Periphyton AFDM was very similar to trends seen with chlorophyll a. The one notable difference is the Soda Butte locations had larger amounts of AFDM than was represented with the chlorophyll a measurement. High algal biomass often indicates nutrient enrichment (Mill Creek/Lion and Tom Miner/ Horse Creek) but high algal biomass also can accumulate in less productive habitats after long periods of stable flow, which may explain why Soda Butte Creek has higher algal AFDM than the Cache Creek sites. Surber samples for the August 2000 and 2001 sampling date have been processed but the aquatic macroinvertebrates remain to be identified, counted, and weighed. Supporting tables and figures for these results can be obtained by contacting the Principal Investigator.

Project title: Fire Effects in Yellowstone National Park

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Objective: 1) Monitor the effects of prescribed and natural fires on Yellowstone's ecosystems, 2) provide information to evaluate whether prescribed burns meet management objectives, and 3) refine our ability to predict fire behavior and fire effects through applied research.

Findings: The Yellowstone Fire Effects Monitoring crew is part of the National Park Service's overall Prescribed Fire Program. In Yellowstone our responsibilities include monitoring the long-term effects of wildland fire-use fires (prescribed natural fires), management ignited prescribed fires, and monitoring of other issues regarding wildland fire as an ecosystem process. In 2001 the Yellowstone Fire Effects Crew: 1) re-read our three Wildland Fire Use monitoring plots which burned last year: Boundary Fire and Two-Smokes Fire. We also resampled a Wildland Fire Use monitoring plot installed in 1997 by Don Despain in the 1996 Coyote Burn. 2) We installed four Wildland Fire Use FMH plots on our Sulphur, Stone, Little, and Falcon Fires. Three of the four plots burned. 3) Pre-burn FMH plots were re-read in our proposed hazard fuel reduction burn at Grant Village. This burn was not implemented in 2001. 4) We installed our first pilot plots for our mechanical treatment for hazard fuel reduction monitoring type at Deaf Jim and Crevice Cabins. These units are slated for hazard fuel reduction using chainsaws. The Deaf Jim plot, however, was converted from the mechanical treatment monitoring type to a fifth wildland fire use plot when the Little Joe Fire consumed both the plot and the cabin. 5) The Little Joe Fire also burned one of our FPSME1T08 plots established in 1999 in a prescribed burn unit in the Electric Peak drainage. This plot and seven others were installed to monitor a prescribed burn which was not implemented. After this plot burned we also converted it to our wildland fire use monitoring type. 6) We resampled the entire set (11 plots) of post-fire vegetation monitoring plots installed by Don Despain (USGS). These plots were established in 1977, 1979, and 1988 ahead of wildfires and will provide valuable information on pre-fire condition and post-fire vegetation recovery in Yellowstone. 7) We resampled the entire set of fireline explosive (FLE) transects established around the park in 1996. This study seeks to understand the effects of FLE as a fireline construction method on vegetation recovery. 8) Our Fire History project is mostly completed. Data on fire perimeters in the archive have been researched and collated into a single database. Historical large fire perimeters dating from early in the century have been entered into a GIS. Smaller fires have also been plotted. This record is reliable back to about 1928 with sporadic records extending into the late 1800s. 9) In late May we hosted students from the University of Iowa and the University of Utah who helped us sample the bulk density of coarse woody debris in four lodgepole pine cover types in Yellowstone. This information will allow us to predict heavy fuel consumption using spatial analysis. One of the students will use the data as her senior project. 10) We plan to issue the second annual newsletter of the NPS Fire Effects Monitoring Program, Rx Effects in June as NPS fire effects crews in the region come on (www.nps.gov/yell/technical/fire/rxfx.htm). 11) We also maintain a website describing our activities (www.nps.gov/yell/technical/fire/effects.htm).